United States
Environmental Protection
Agency

Research and Development

Municipal Environmental Research
Laboratory
Cincinnati, OH 45268

EPA-600/S2-82-102 Mar. 1983

EPA

Project Summary

Determination of Explosion Venting Requirements for Municipal Solid Waste Shredders

Robert G. Zalosh, John P. Coll, and David M. Goertemoeller

A gas explosion test program was conducted in a realistic, full-scale mock-up of a municipal solid waste shredder. The 61-m^3 (2200-ft^3) mock-up simulated a horizontal-shaft hammermill (including rotating shaft, discs, and hammers, but without trash) with a large, inclined feed hood. Varying amounts of propane were injected into the shredder, and the resulting gas concentrations generated by rotor-induced mixing were measured. Eight propane explosion tests were also conducted with varying volumes of near-stoichiometric propane-air mixtures and various hammermill shaft speeds. Tests indicated that venting through the top of the shredder effectively kept pressures under 41 kPa (6 psig) at shredder shaft speeds of 250 to 660 rpm with 16 hammers; but pressures reached 69 to 103 kPa (10 to 15 psig) at a shaft speed of 900 rpm with 48 hammers.

The pressures generated with a hammermill shaft speed of 900 rpm and 48 hammers were much larger than would have been expected on the basis of current guidelines for explosion venting design. New guidelines are suggested that include a quantitative relationship between peak pressure and shaft speed. The recommended guidelines also discuss the effects of vent ducting, vent covers, and blast waves emitted during a shredder explosion.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In recent years, shredding of municipal solid waste (MSW) has become a common processing step before land disposal, resource recovery, or incineration. Because it is virtually impossible to screen the input stream thoroughly, potentially explosive materials such as gasoline, propane, paint thinner/cleaner, gunpowder, etc. occasionally enter the shredder. An explosion can occur from ignition of these materials by impact sparks or hot spots generated during shredding (hammering).

Explosion venting is the most popular method used to control shredder explosions. The principle of explosion venting is to prevent pressure buildup in the shredder by allowing an incipient pressure rise to actuate blowout panels or curtains so as to vent unburned gas and combustion products.

Existing explosion venting guidelines may not be adequate for the more challenging shredder explosion applications. Previous explosion venting design criteria are based on tests involving simple structures such as rooms or spherical or cylindrical pressure vessels. But MSW shredders represent a more severe explosion environment because of the effects of rotor windage/turbulence and internal obstructions (shaft, hammers, breaker plates, trash, etc.).

The objective of this project was to develop and test explosion venting requirements for MSW shredders. The approach was to perform gas explosion tests in a realistic, full-scale, mock shredder outfitted with a typical explosion vent configuration employed at several MSW shredding facilities.

Shredder Mock-up

The full-scale mock-up of a large, horizontal-shaft hammermill was constructed at the Factory Mutual Research Test Center in West Glocester, Rhode Island. The mock-up, which had the approximate size and shape of the Williams 680* shredder was 8.23 m (27 ft) high with a total internal volume of 62 m^3 (2200 ft^3), including a 19-m^3 (660-ft^3) inclined inlet hood (Figure 1). The shredder structure consisted of a steel frame with 3.8-cm-thick (1.5-in.-thick) plywood walls. The frame and sheet-metal-clad walls were designed to withstand an internal quasi-static explosion pressure of 34.5 kPa (5 psig).

Some of the 1.2- x 1.2-m (4- x 4-ft) plywood panels were fastened with collapsible washer-type explosion vent fasteners so that the panels could blow off at a prescribed static overpressure during the explosion tests. In most of the tests, venting was accomplished by deploying four panels on top of the shredder. The total vent area of the four panels was 5.1 m^2 (55 ft^2). Additional venting capacity was available through the inlet hood and the bottom discharge areas.

The hammermill shaft on the mock-up was outfitted with 24 91-cm-diameter (36-in.-diameter), 2.5-cm-thick (1-in.thick) plywood discs. Two simulated hammers in the form of 38-cm-long (15-in.-long) aluminum bars can be fastened to each of the discs. In the first seven explosion tests, only 16 hammers were installed. In the last test, all 48 hammers were installed.

Most of the tests were conducted with a 2.2-kW (3-hp) motor driving the shaft by means of a variable speed drive unit to generate shaft speeds in the range 250 to 690 rpm. In the last explosion test, the 3-hp motor was replaced by a 30-hp motor with a fixed speed transmission driving the shaft at 900 rpm.

No trash was put into the shredder mock-up. Placing trash in the shredder would have caused an obstruction in the inlet and discharge areas. This was simulated in the mock-up by covering the 5.5-m^2 (59-ft^2) inlet area and the 2.76-m^2 (29.7-ft^2) discharge area with polyethylene sheets in many of the tests.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Procedures

Gas Mixing and Flow Visualization Tests

Before the explosion tests, flow visualization and gas mixing tests were conducted to determine how flammable gas-air mixtures might form during a shredder explosion. The procedure involved placing an intact flammable vapor container in the shredder and allowing it to be broken by the hammer impact. Flammable vapor released from the broken container is diluted by the rotor-induced air flow. Flow visualization tests were designed to reveal induced air-flow patterns causing gas dilution. The gas mixing tests were designed to determine the spatial and temporal extent of flammable gas-air mixtures formed during this scenario.

In the flow visualization tests, a chemical smoke candle placed near the hammermill shaft was lit and the resulting smoke pattern was observed. In some of these tests, a translucent polyethylene covering replaced the plywood panels on the front wall of the shredder. Most of the smoke remained in the vicinity of the mill area for 1 to 3 minutes before diluted smoke began to exit through the discharge grating at the bottom of the shredder.

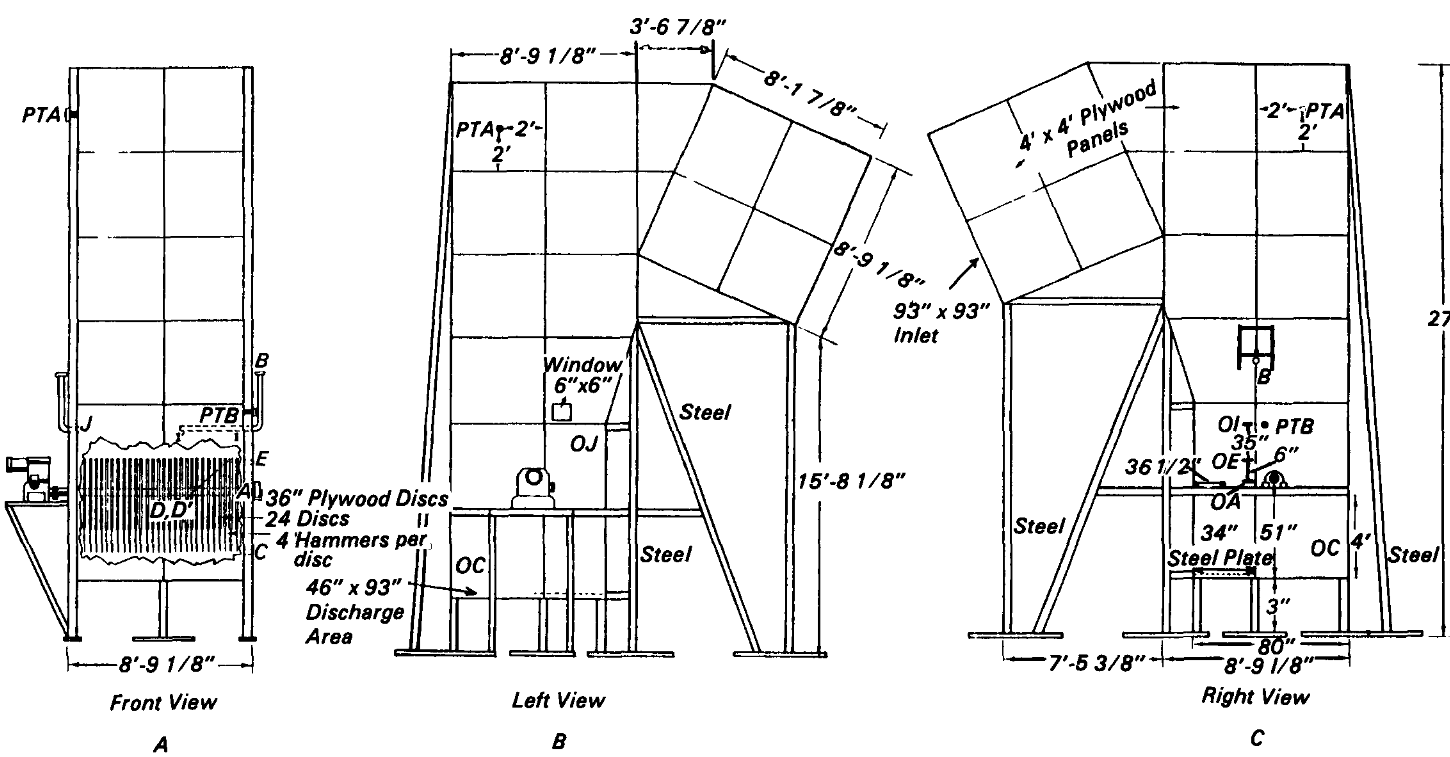

Figure 1. *Shredder mock-up.*

A preweighed quantity of propane was used for the gas mixing and explosion tests. The gas mixing tests were conducted by rapidly injecting the propane into the hammermill portion of the shredder. Three differnt injection locations (I, I', and J in Figure 1) were used. Injection at I' was achieved with a 81-cm (36-in.) horizontal extension from I. Liquid phase propane was used in all but one of the tests. Propane concentrations were measured with an Anarad AR-400 infrared gas analyzer with a calibrated range of 0% to 8% propane by volume and a response time of 5 to 15s, depending on sample location. (The latter are designated as locations A, B, C, D, D' (extension of pipe D), and E in Figure 1). Peak concentration data for all gas mixing tests are listed in Table 1.

Explosion Test Procedure and Instrumentation

Explosion tests in the shredder mock-up were conducted with propane-air mixtures of varying size and concentrations in the range 3.5% to 4% by volume. An electric match was used to ignite the gas mixture in the first few tests; later tests were fired by a 12-joule condenser spark discharge.

Gas mixtures for the first two tests were formed by rotor-induced mixing with open inlet and discharge areas. But this unrestrained mixing resulted in a very weak explosion in the first test and in no explosion at all (after three attempts) in the second test. Subsequent tests were therefore conducted by confining the gas mixture with polyethylene sheets.

In the first seven explosion tests, pressures were measured with two Dynisco Model PT 321 strain gage transducers with a calibrated range of 0 to 69 kPa (0 to 10 psig). In the last test, Celesco P2805 pressure transducers with a range of 0 to 103.5 kPa (0 to 15 psig) were used. One transducer (labeled Gage A) was mounted on one side wall of the shredder 0.61 m (2 ft) below the top (location PTA in Figure 1). The other transducer (labeled Gage B) was mounted on the other side wall of the shredder 104 cm (41 in.) directly above the shaft (location PTB in Figure 1).

In all but the last test, the four plywood panels on top of the shredder were used for explosion venting. They were outfitted with collapsible washer fasteners so that the nominal panel release pressure was in the range 1.4 to 2.8 kPa (0.2 to 0.4 psig). In the first two tests, pressures did not reach these values, so the vent panels did not deploy. In subsequent tests, the panels did deploy, but not until the pressure reached 7.6 to 17.2 kPa (1.1 to 2.5 psig). In the last test, the plywood panels were replaced with a 0.10-mm-thick (4-mil-thick) polyethylene film designed for a nominal tear pressure of 2.1 kPa (0.3 psig).

Explosion Test Results

Test conditions and peak pressure data are outlined in Table 2. Seven tests were run, not including the misfire in Test 2. Peak pressures ranged from a low of 1.0 kPa (0.15 psig) in the first test to a high of 106.3 kPa (15.4 psig) in the last test. Peak pressures measured by Gage A at the top of the shredder were consistently higher than those measured by Gage B in the hammermill section of the shredder. The test sequence involved generally increasing explosion severity. In the last test (Test 8), the unexpectedly high peak pressure produced significant damage to the shredder. The violent explosion caused weld failures, deformation of members of the steel frame, and bolt fastener failures, which allowed the plywood panels to blow off the stucture.

Conclusions

Test results lead to the following conclusions:

1) The probability and severity of an MSW shredder explosion depend greatly on the amount of flammable gas released, the presence of obstructions in the inlet and discharge area, and the hammermill shaft speed and number of hammers.
2) Explosion venting effectiveness is quite sensitive to shredder turbulence level as determined by shaft speed and number of hammers.
3) If existing explosion vent design guidelines are used, little or no credit should be taken for venting through shredder inlet and discharge areas.

Appendix A of the full report contains guidelines for shredder explosion venting based on test results, analysis, and a review of other published explosion venting design criteria.

The full report was submitted in fulfillment of Contract No. 68-03-2880 by Factory Mutual Research Corporation under the sponsorship of the U.S. Environmental Protection Agency.

Table 1. *Gas Mixing Data*

Test No.	Shaft Speed (rpm)	Injector Location	Total wt of fuel (lb)	Sample Location: A		B		C		D		D'		E		Open or Closed Bottom
				C_{max}*	T†	C_{max}	T	C_{max}	T	C_{max}	T	C_{max}	T	C_{max}	T	
1	260	I	1	>8	25	0.5	-	2.0	-	1.6	-	-	-	-	-	Open
2	680	I	1	3.25	10	-	-	-	-	0.8	-	0.9	-	5.5	10	Open
3	690	I'	1	-	-	-	-	-	-	1.5	-	1.1	-	0.5	-	Open
4	480	I	1	2.75	-	-	-	-	-	1.0	-	1.0	-	-	-	Open
5	690	I,J	2	4.0	18	-	-	-	-	1.0	-	-	-	-	-	Open
6	660	I,J	3	8.0	31	-	-	-	-	-	-	-	-	-	-	Open
7	660	I,J	2	2.6	6	-	-	0.5	-	1.6	-	-	-	-	-	Open
8	660	I,J	2	3.6	20	-	-	-	-	-	-	-	-	-	-	Closed
9	660	I,J	2	7.5	15	-	-	-	-	-	-	-	-	-	-	Closed
10	660	I,J‡	2	1.6	-	-	-	-	-	-	-	-	-	-	-	Closed

*C_{max} = *maximum concentration (vol %).*
†*T = duration of flammable concentration(s).*
‡*Propane gas injected in the gas phase (top injection) in the last test and in the liquid phase (bottom injection) in the first eight tests.*

Table 2. Shredder Explosion Test Data

Test No.	Propane Concentration (%)	Mixture Volume (ft^3)	Mixture Volume (% of Shredder)*	Shaft Speed (rpm)	Vent Area† (ft^2)	Vent Release Pressure (psig) Static	Vent Release Pressure (psig) Actual	P_{max} (psig)‡ Gage A (Top)	P_{max} (psig)‡ Gage B (Mill)
1	2.4	Uncontrolled Mixing		690	0	0.4	-	0.15	-
3∮	3.5-4.0	700	(44)	690	55	0.4	2.5	2.7	2.6
4	4.0	700	(44)	438	55	0.3	1.1	1.3	1.1
5	3.8	700	(44)	660	55	0.3	#	2.0	1.7
6	3.6	1600	(100)	250	55	0.2	1.3	4.8	3.1
7	3.7	1600	(100)	660	55	0.2	1.75	-	4.3
8	3.9	1600	(100)	900**	55	0.3	1.7	15.4	9.5

* Percentages of shredder volume are based on volume excluding inlet hood.
† Vent area does not include shredder discharge area or inlet hood area.
‡ psig = 6.9 kPa.
∮ Test 2 did not produce an explosion because the uncontrolled mixing resulted in the ignitor firing a few seconds too late.
The actual vent release pressure is not known for Test 5 because the oscillograph was started too late.
** 48 simulated hammers were installed on the shaft in Test 8; only 16 hammers were used in Tests 1-7.

Robert G. Zalosh and John P. Coll are with Factory Mutual Research Corporation, Norwood, MA 02062; and the EPA author ***David M. Goertemoeller*** *is with the Municipal Environmental Research Laboratory, Cincinnati, OH 45268.*
Carlton C. Wiles *is the EPA Project Officer (see below).*
The complete report, entitled "Determination of Explosion Venting Requirements for Municipal Solid Waste Shredders," (Order No. PB 83-149 088; Cost: $10.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U.S. Government Printing Office: 1983-659-017/7024